SLOW RATE LAND APPLICATION OF LAGOON WASTEWATER AT SAYLORVILLE LAKE RECREATIONAL FACILITIES

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BACKGROUND

Current annual campground usage of the recreational sites Cherry Glen and Prairie Flower generates more sewage effluent influx to the three holding cells at each site than the cells are capable of holding. Plastic cell liners, which were required by the Iowa Department of Natural Resources, greatly reduced the cell's capability to naturally percolate the ponded effluent. Since evaporation alone was not sufficient in reducing the pond elevations and overland flow was not desirable by the Iowa DNR, another more controlled and measurable means of disposing of wastewater was needed.

WASTEWATER TREATMENT

The treatment process for both Cherry Glen and Prairie Flower consists of aerobic stabilization within retention pond systems. Sewage from each site is delivered to the first of three interconnected shallow earthen basins where the treatment occurs. The treatment of the wastewater is accomplished naturally through the use of algae and bacteria within the ponds. Oxygen in the pond is utilized by bacteria to perform aerobic degradation of the pond’s organic matter. Nutrients and carbon dioxide released by the bacteria are used by the algae. The algae, in turn, release more oxygen for the bacteria to further breakdown the organic matter. This process completes the wastewater treatment cycle. Thus, wastewater treatment continues by this method of oxygen and carbon dioxide exchange.

WASTEWATER QUALITY

Iowa State University was contracted to perform the chemical tests on wastewater samples from the finish cell of each lagoon system. The lagoon wastewater was tested for a variety of constituents as outlined in Chapter 21 of the Iowa Wastewater Facilities Design Standard [1]. The test results are given below in Table 1.

TABLE 1
WASTEWATER CHEMICAL TEST RESULTS

MAJOR CONSTITUENT	CHERRY GLEN WWTR SAMPLE	PRAIRE FLOWER WWTR SAMPLE
Total Organic Carbon	20 mg/l	14.1 mg/l
Total Dissolved Solids	204 mg/l	289 mg/l
Sodium Absorption Ratio	0.9	0.3
Electrical Conductivity	302 umhos/cm	494 umhos/cm
Total Kjeldahl Nitrogen	7.00 mg/l	3.4 mg/l
Ammonia Nitrogen	Not Detected	0.16 mg/l
Organic Nitrogen	7.00 mg/l	3.24 mg/l
Nitrate Nitrogen	Not Detected	Not Detected
Dissolved Phosphorous	0.34 mg/l	2.24 mg/l
Chloride	27 mg/l	14 mg/l
PH	8.42	7.18
Total Alkalinity	73.6 mg/l as $CaCO_3$	193.8 mg/l as $CaCO_3$
Total Hardness	92.0 mg/l as $CaCO_3$	200.0 mg/l as $CaCO_3$
Calcium Hardness	56.0 mg/l as $CaCO_3$	125.0 mg/l as $CaCO_3$
TRACE ELEMENTS		
Aluminum	0.17 mg/l	0.19 mg/l
Arsenic	Not Detected	Not Detected
Beryllium	Not Detected	Not Detected
Boron	0.13 mg/l	0.05 mg/l
Cadmium	Not Detected	Not Detected
Chromium	Not Detected	Not Detected
Cobalt	Not Detected	Not Detected
Copper	Not Detected	Not Detected
Fluoride	0.2 mg/l	0.3 mg/l
Iron	Not Detected	0.36 mg/l
Lead	Not Detected	Not Detected
Lithium	Not Detected	Not Detected
Manganese	Not Detected	0.1 mg/l
Molybdenum	Not Detected	Not Detected
Nickel	Not Detected	Not Detected
Selenium	Not Detected	Not Detected
Vanadium	Not Detected	Not Detected
Zinc	0.02 mg/l	0.02 mg/l
Total Coliform	None Found	1300 Organisms/100 ml

Bacteria		

WASTEWATER QUANTITY

The volume of wastewater inflow over a 3-year period was estimated to be 2.0 and 2.5 million gallons per year, for Cherry Glen and Prairie Flower, respectively. The estimated wastewater volumes for both recreational areas was based on an analysis of the facilities at each site, (campsites, comfort stations, shower buildings, shelters, etc.) and the average visitation (both campers and day-users). With net evaporation of each pond system estimated to be 767,000 and 950,000 gallons per year, the net drawdown of wastewater from the lagoon systems to maintain proper operating levels was determined to be approximately 1.3 and 1.6 million gallons per year for each site. The number of operating days/season at each location is 220. Therefore, the average accumulating quantity of inflow/day, during the operating season and excluding precipitation, at Cherry Glen and Prairie Flower is 5,900 and 7,300 gallons/day, respectively.

DESIGN CHALLENGES

The goal of the design was to control holding cell elevations by introducing sewage effluent to the ground by a controllable application method. It was necessary to design the controlled application method to not exceed the allowable limits for soil percolation, Nitrogen loading, and Phosphorus loading as established by the Iowa Wastewater Facilities Design Standards. Environmental engineers analyzed these criteria for the proposed disposal sites and determined the limiting factor to be the allowable annual hydraulic loading rate based on soil permeability. The Environmental engineers established the minimum application area and the frequency of applications required for each site. Neither the feasible soil hydraulic loading rate nor the maximum hydraulic rate established by state standards could be exceeded during an application. If the first is exceeded the soil would become saturated and overland flow would occur. If the second is exceeded the method of application is in violation of state standards.

AESTHETICS

Both Cherry Glen and Prairie Flower have their sewage lagoons in close proximity to publicly accessible areas. In the case of Cherry Glen the lagoons border along a public bike trail. Prairie Flower’s lagoons are very near the campgrounds they serve. The challenge was to design a project which could apply the wastewater to the designated application areas without utilizing conventional aboveground sprinkler systems. The problem posed by aboveground sprinklers is that the spray and mist from the sprinklers becomes air borne. The air borne mist vaporizes and can carry offensive odors to areas occupied by the public. This was not acceptable to the customer or designer.

OPERABILITY

The customer requested the application areas require minimal maintenance. This meant only annual mowing would be performed in the fenced application areas. Taller grass in these areas would restrict the use of above ground sprinklers. Above ground sprinklers run the risk of not functioning properly in taller grass, thus, creating non-treated and saturated areas during an effluent application. Above ground sprinklers also require periodic maintenance/repair because of their mechanical design.

DESIGN METHOD

Subsurface emitterlines were best suited to apply the treated effluent to the application areas and meet the design challenges as stated above. Emitterlines designed for effluent disposal were found to be superior to conventional irrigation emitterlines for the following reasons:

- Emitters are designed with turbulent flow paths to pass particles easily.

- Raised emitters reduce sediment accumulation.

- Emitters and tubing are chemically treated to provide extended protection against root intrusion and slime growth.

- Emitters have a wide operation of pressures to assure uniform flow rates along the entire emitterline.

- A purple color coding of the emitterlines identifies the line is from a non-potable source.

SUBSURFACE APPLICATION ADVANTAGES

The subsurface drip method of effluent disposal was deemed the most efficient method for the conditions at Saylorville Lake. The main advantages associated with a subsurface disposal system are:

- Minimizes health risks.

- Systems can be easily automated.

- Installations are invisible and virtually vandal proof.

- Systems are non-intrusive and can allow for use of the space while effluent is being applied.

- Durable systems with long useful lives can be installed.

- Minimizes deep ground percolation.

- Subsurface systems increase consumption of nitrates and water by means of use and evapotranspiration in plants.

- Subsurface systems are well suited for difficult conditions arising from high water tables, tight soils, steep or uneven terrain, and prevailing high wind areas.

- Surface puddling or runoff will not occur from well-designed systems.

SYSTEM COMPONENTS

The underground emitter system was designed to deliver effluent from the third holding cell at Cherry Glen and Prairie Flower to the emitter application areas. Effluent is pumped to the emitter fields by a single electric 5 HP submersible grinder pump at each site. A flow rate of 53 GPM @ 76’ TDH was sized for the Cherry Glen location. Prairie Flower was slightly larger with a 65 GPM flow rate @ 106’ TDH. The governing factor in determining the pump size was the system flushing velocity and not the maximum volumetric quantity of effluent to be applied per application per month. Electric power was available to power the pump at the Prairie Flower site and a small diesel generator was incorporated into the design at the Cherry Glen site. The pumps are submerged into manholes that are connected by ductile iron pipe to the bottom of the holding cells. The effluent is pumped through PVC piping to 140 mesh filters with manual backflush capabilities and is totaled by a water meter prior to emitter line delivery. The PVC supply header piping delivers the pumped effluent to each emitter field zone. Each system for this project contained two emitter zones. The zones encompass isolation valves, a portion of the PVC supply header pipe, the lateral emitter coils, air/vacuum relief valves, pressure gauges, check valves, and a portion of the PVC return header pipe. The zones are necessary to isolate portions of the system to achieve a minimum flushing velocity of 2 ft./sec. in the emitter lines. Periodic flushing and backflushing of the emitter lines and filters is very important to prevent slime and sedimentation buildup. The PVC return header pipe is designed to return flushed effluent and filter sedimentation to the third holding cell at Cherry Glen and Prairie Flower. Typical system layout for each location is shown in Figure 1.

INSERT FIGURE 1. SYSTEM LAYOUT

PROJECT COSTS

The project was bid as one lump sum and had a contract period of 174 days. The physical characteristics of the job included but were not limited to the installation of underground piping, emitter lines, valves, filters, water meters, a manhole at Prairie Flower, grinder pumps and assemblies, electrical service, a generator at Cherry Glen, fence and seeding. The Government estimate to complete the project was $118,600 and the contract was awarded for $107,281. The only two specialty items associated with the project included the emitter line and the filters. The emitter line cost range was from $0.30 - $0.52 per foot. The three inch 140 mesh angle filters cost approximately $670 each. Each site had two filters incorporated into the design and emitter line lengths were approximately 10,300 feet.

ENGINEERING CONSIDERATIONS FOR CONSTRUCTION AND CUSTOMERS

Engineering considerations provided to Construction personnel to assist in contract administration and minimize field questions related to design intent are outlined by the following:

- The contract specifically requested the Contractor to excavate, lay in the emitter lines, and over backfill for natural settlement of the ground. The thought process governing trenching vs. plowing was that open trench installation would allow for better inspection of the system in the field by Construction personnel. Visual inspection provides better quality control than plowing the emitter lines. Engineering would support the vibratory plow method of installation if Construction desired to inspect this method and the emitter line manufacturer approved this type of installation.

- The basis of design for this project was Netafim emitter line manufacturer and their associated components. The specifications indicated stringent requirements upon the system installation. If deviations from the design were deemed necessary by the Contractor, submittal of those proposed changes were required by the Contractor and costs associated with those changes should be at the Contractor’s expense.

- The Contractor was required to install emitter lines and piping to minimize the number of low points within each system. The minimization of low points will aid in the winterization of the system.

- A quick connect coupler located just beyond the water meter was installed to provide the means of winterizing each system. By connecting compressed air to the connector each system can be cleared of water by blowing the system out. The connector also provides a point of connection for chemical injection should root intrusion ever be experienced within the emitter lines.

SYSTEM OPERATION

A sequence of system operation was provided for benefit to Construction, the customer and the Contractor to understand Engineering’s philosophy for startup procedure. Since Cherry Glen has the more complex system with the inclusion of the generator it will be outlined below. The following sequence can be referenced to Figure 1 identified earlier in the text.

1. Close first valve downstream of the water meter and close shut-off valve located in the flush header.

2. Close valve to right of tee fitting downstream of first pressure gauge and open valve to left of tee.

3. Close valve to left of tee fitting which returns to flush header and open valve to right of tee returning to flush header. Both of these valve are located downstream of the valves described in step 2 above.

4. Perform generator engine maintenance as required checking all fuel, fluid and lubrication levels. Start generator and allow to warm up. (IMPORTANT - The operator will have 5 minutes adjustable to 10 minutes to start the pump immediately following the start up of the generator. If the pump is not started within the 5 minutes the generator will shut down and require restarting by the operator. This automatic generator shut down feature prevents the generator from running all day should the pump stop for any reason.)

5. Start the pump to begin flushing the right 3” angle disc filter into cell 3. Operator shall visually inspect to verify flushed effluent is returned to cell 3. Allow flushing of disc

filter to continue for 3 minutes or until filter is cleaned thoroughly.

6. Stop the pump and perform the opposite opening and closing of valves as described in steps 2 and 3. This will prepare the left 3” angle disc filter to be flushed. Remember that once the pump is stopped 5 minutes is allowed to perform the valve maneuver prior to the generator shutting down.

7. Start the pump and flush the left 3” angle disc filter for the same amount of time as described in step 5.

8. Stop the pump. Remove the filter cartridges of both disc filters and inspect for cleanliness then reinstall. Repeat flushing operations as described above as necessary. A second option to flushing the disc filters is to have a spare set of filters on hand. The spare set of disc filter cartridges can be substituted for the installed set at the beginning of each application. The dirty set can then be cleaned manually away from the site and stored until the next use.

9. Open the valve to the left of the tee and close the valve to left of tee fitting which returns to flush header. Open the valve downstream of the water meter and open the shut-off valve in the flush header.

10. Close the shut-off valve leading to ZONE B and open the valve leading to ZONE A.

11. Start the pump and flush ZONE A for 5 minutes or until pump discharge from return header appears free of particulate matter and sediment.

12. Shut off the pump and reverse valve sequence for ZONE A and ZONE B.

13. Start the pump and flush ZONE B as described in step 11.

14. Open the valve leading to ZONE A and let ZONE B shut off valve remain open. Close the shut-off valve in the flush header to prepare the system for application.

15. Start pump to begin application. Set shut off timer (0-12 hrs) to the desired number of hours of application. Walk away. System will automatically shut down at the end of the application time or if a system malfunction occurs. The

operator should periodically monitor pressure gauges within the system to identify excessive pressure drops. Large pressure drops will indicate a blockage and a need to backflush the disc filters or flush the zones. Monitoring of the water meter should also be performed to calculate the volume of effluent being applied per application. The volume applied per application should not exceed the maximum allowed. Column (3) and (5) in Table 2 identify maximum volumes and application times.

TABLE 2
CHERRY GLEN APPLICATIONS

ONE APPLICATION PER WEEK: Area of application = 0.5 acre					
MONTH	(1) Hydraulic Loading Rate Lw (in./mo.)	(2) Inches/ Applicatio n (in./app.)	(3) Gallons/ Applicatio n See (*Note)	(4) Gallons/ Month (2)*(4)	(5) Hours/ Applicatio n (@ 53 GPM) (hr./app.)
APR	0	0	0	0	0
MAY	1.43	0.36	4887	19548	1.5
JUN	4.59	1.15	15612	15612	4.9
JUL	8.16	2.04	27695	110780	8.7
AUG	9.45	2.36	32039	128156	10.1
SEP	9.12	2.28	30953	123812	9.7
OCT	7.40	1.85	25116	100464	7.9
NOV	3.06	0.77	10453	41812	3.3
ANNUAL TOTAL	43.21			524572	
Note: Column (3) is based on the following: (gal/app)=(in/app)(conversion)*(area of application) ex:(gal/app)=(.36 in/app)*(27,152 gal/in*ac)*(0.5 ac) = 4887 gallons/application					

The balance of the 1.3M gallon annual wastewater volume not accounted for by column (4) of Table 2 above will be removed from the pond system by adjusting the number of applications per week. This will be done as weather permits during the camping season. Lower precipitation periods will allow for multiple wastewater applications per week. Another alternative is to allow the ponds to accumulate wastewater and increase the frequency of application at the end of the camping season. The third option, in extremely wet years, is to allow the pond systems to store wastewater until conditions permit for wastewater applications to occur. The pond systems at both Cherry Glen and Prairie Flower have approximately a two-year storage capacity assuming normal conditions.

LESSON LEARNED

Upon construction completion the Contractor was required to perform startup testing at each site. During short periods of testing, premature clogging of the disc filters caused major operational difficulties for each site. Water samples collected at various depths from the finishing cell at the Cherry Glen site revealed Total Suspended Solids levels to average 21.4 mg/l. Samples taken from the pump manhole supplying the effluent to the system had TSS measurements of 74 mg/l and 100 mg/l. This lead to the conclusion the pipe intakes leading to the pump manholes were to close to the bottom of the finishing cells. Therefore, effluent delivered to the pump manholes had high concentrations of Total Suspended Solids. Hence, the disc filters became prematurely clogged. After consulting with the emitter line manufacturer it was concluded the pipe intake should be raised. The most suitable depth for the pipe intakes was determined to be mid depth within the finish cells. A mid depth location places the pipe intake above the high concentration of suspended solids at the bottom of the finish cells and below the algae that forms near the surface of the finish cells. As a result, the intakes were raised and assembled with an upside u-pipe at the point of intake. This solved the problem with the premature filter clogging.

MANUFACTURERS

Two known manufacturers of wastewater application products and design literature include;

- Netafim Irrigation Inc., East Coast Office: 548 N. Douglas Ave., Altamonte Springs, FL 32714, Tel(407) 788-6352, Fax(407) 862-0259, West Coast Office: 3025 E. Hamilton, Fresno, CA 93721, Tel(209) 498-6880, Fax(209) 442-3119

- Geoflow Inc., 200 Gate Five Road, #103 Sausalito, CA 94966, Tel(415) 331-0166, Fax(415) 331-0167

CONCLUSION

Treatment and disposal of sewage wastewater is becoming increasing more difficult to accomplish. More stringent regulations and laws make design of wastewater treatment systems challenging. Subsurface disposal designs offer an alternative method to wastewater disposal. Their simplistic designs offer many benefits in operation, maintenance, and land usage when compared with surface applied systems. Where a controlled method of wastewater disposal is desired, subsurface application systems should be considered as a viable alternative of wastewater treatment.

REFERENCES

1. Iowa Wastewater Facilities Design Standards, Chapter 21, Land Application of Wastewater, 25 April 1979.

AUTHOR'S ADDRESS

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~~The soil permeability conditions vary throughout the year, at each site, depending upon the season. The allowable hydraulic loadings for both locations are shown in Table 2 and Table 3. The hydraulic loading rates were calculated using a 10 year frequency design precipitation, an estimated evapotranspiration rate of reed canary grass, an annual operation period of 7 months per year (approximately 220 camper-days) and 4% of the minimum infiltration rate of 0.6 inches per hour for the design percolation rate. The water balance per month of operation and the design wastewater hydraulic loading rate (Lw) is as follows.~~

~~TABLE 2~~

~~PRAIRIE FLOWER HYDRAULIC LOADING RATE BASED ON SOIL PERMEABILITY (INCHES/MONTH)~~

	~~WATER LOSSES (INCHES)~~		~~=~~	~~WATER APPLIED (INCHES)~~		
~~(1)~~	~~(2)~~	~~(3)~~	~~(4)~~	~~(5)~~	~~(6)~~	~~(7)~~
	~~EVAPOTRANSPIRATION, ET~~	~~DESIGN PERCOLATION, Wp~~	~~TOTAL~~	~~PRECIPITATION, P~~	~~WASTEWATER, Lw~~	~~TOTAL~~
~~MONTH~~	~~(INCHES)~~	~~(INCHES)~~	~~(2)+(3)~~	~~(INCHES)~~	~~(4)-(5)~~	~~(5)+(6)~~
~~APR~~	~~0.00~~	~~8.64~~	~~8.64~~	~~4.36~~	~~4.28~~	~~8.64~~
~~MAY~~	~~0.70~~	~~10.00~~	~~10.7~~	~~5.81~~	~~4.89~~	~~10.7~~
~~JUN~~	~~5.16~~	~~10.00~~	~~15.16~~	~~6.90~~	~~8.26~~	~~15.16~~
~~JUL~~	~~7.43~~	~~10.00~~	~~17.43~~	~~5.81~~	~~11.62~~	~~17.43~~
~~AUG~~	~~8.41~~	~~10.00~~	~~18.41~~	~~5.50~~	~~12.91~~	~~18.41~~
~~SEP~~	~~7.01~~	~~10.00~~	~~17.01~~	~~4.22~~	~~12.79~~	~~17.01~~
~~OCT~~	~~4.20~~	~~10.00~~	~~14.20~~	~~3.34~~	~~10.86~~	~~14.20~~
~~NOV~~	~~2.23~~	~~8.64~~	~~10.87~~	~~2.33~~	~~8.54~~	~~10.87~~
~~TOTAL ANNUAL~~	~~35.14~~	~~77.28~~	~~112.42~~	~~38.27~~	~~74.15~~	~~112.42~~

~~TABLE 3~~

~~CHERRY GLEN HYDRAULIC LOADING RATE BASED ON SOIL PERMEABILITY (INCHES/MONTH)~~

	~~WATER LOSSES (INCHES)~~		~~=~~	~~WATER APPLIED (INCHES)~~		
~~(1)~~	~~(2)~~	~~(3)~~	~~(4)~~	~~(5)~~	~~(6)~~	~~(7)~~
	~~EVAPOTRANSPIRATION, ET~~	~~DESIGN PERCOLATION, Wp~~	~~TOTAL~~	~~PRECIPITATION, P~~	~~WASTEWATER, Lw~~	~~TOTAL~~
~~MONTH~~	~~(INCHES)~~	~~(INCHES)~~	~~(2)+(3)~~	~~(INCHES)~~	~~(4)-(5)~~	~~(5)+(6)~~
~~APR~~	~~0.00~~	~~3.16~~	~~3.16~~	~~4.36~~	~~(-)1.20 =0~~	~~3.16~~
~~MAY~~	~~0.70~~	~~6.54~~	~~7.24~~	~~5.81~~	~~1.43~~	~~7.24~~
~~JUN~~	~~5.16~~	~~6.33~~	~~11.49~~	~~6.90~~	~~4.59~~	~~11.49~~
~~JUL~~	~~7.43~~	~~6.54~~	~~13.97~~	~~5.81~~	~~8.16~~	~~13.97~~
~~AUG~~	~~8.41~~	~~6.54~~	~~14.95~~	~~5.50~~	~~9.45~~	~~14.95~~
~~SEP~~	~~7.01~~	~~6.33~~	~~13.34~~	~~4.22~~	~~9.12~~	~~13.34~~

~~OCT~~	~~4.20~~	~~6.54~~	~~10.74~~	~~3.34~~	~~7.40~~	~~10.74~~
~~NOV~~	~~2.23~~	~~3.16~~	~~5.39~~	~~2.33~~	~~3.06~~	~~5.39~~
~~TOTAL~~						
~~ANNUAL~~	~~35.14~~	~~45.14~~	~~80.28~~	~~38.27~~	~~43.21~~	~~80.28~~

~~The design application area was calculated for each site to be 0.5 acre for Cherry Glen and 0.3 acre for Prairie Flower. The computation accounted for average daily wastewater inflow (ft^3/day), the net loss or gain in stored wastewater volume (ft^3/yr) (P Precipitation, ET Evapotranspiration, Percolation from pond), and the design percolation rate (in/yr). It was determined by the user that a once per week application was acceptable from an operating standpoint. wastewater required at each disposal site was calculated to satisfy the~~